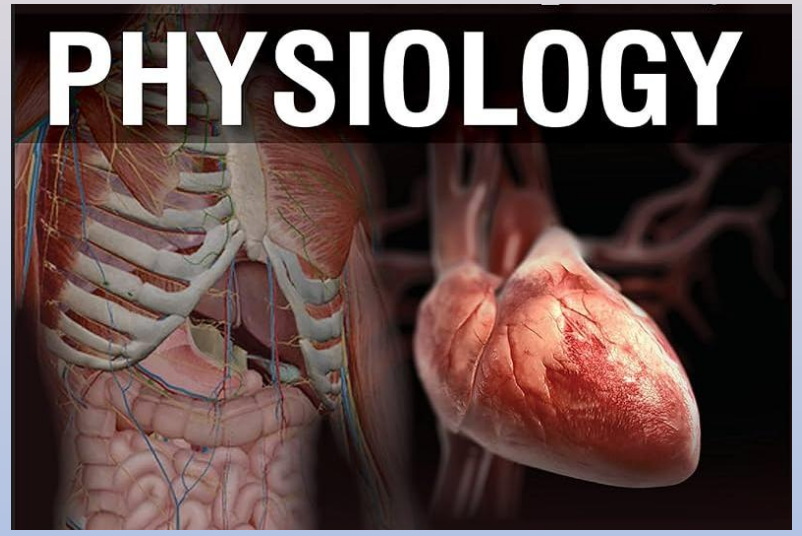
Principles of physiology



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Contents of the course

- Introduction to human physiology
- Cell Physiology
- Excitable Tissues & Control Systems
- Organ Systems Physiology
- Endocrine Physiology

What is Physiology?

- Physiology is the study of the functions of living things. Specifically, we will focus on how the human body works.
- - Explains how cells, tissues, and organs work
- - Answers the question: 'How does the body stay alive and balanced?'

Why do we study physiology

1) **To understand the normal body**

   Physiology explains **how the body works in health.**

   Example: how the heart pumps blood, how lungs exchange gases, how kidneys maintain balance.

2) **To recognize what goes wrong in disease**

   If we know the normal mechanisms, we can understand what happens when they fail.

   Example: knowing normal blood sugar regulation helps us understand **diabetes**.

3) **- It is the foundation for understanding health and disease**

   Physiology links basic biology with clinical practice.

   Doctors, nurses, pharmacists, and health professionals all rely on physiology to make sense of symptoms, treatment, and prevention.

Application in real life

- Sports: improving performance and recovery.
- Nutrition: understanding metabolism.
- Stress & environment: how the body adapts to heat, cold, altitude

Cell 

- The cell is the basic function unit of the living organisms .
- To go up the **Cell** → tissue → organ → system → organism

- To go down the **Cell** → cellular organelles → macromolecules → molecules → atoms

Water

- Water is the main component of the human body (about 60–70% of the body weight).
- It helps move nutrients, remove wastes, and keep cells working.
- The body controls water balance through thirst, kidneys, and hormones.
- Small changes in water can upset balance, so water is vital for homeostasis.

Homeostasis

Homeostasis is the ability of the body to maintain a stable internal environment despite external changes.

• Key Features:

• - Keeps temperature, pH, water, and electrolytes balanced

• - Ensures proper function of cells, tissues, and organs

for normal cellular function water and essential nutrients are required:

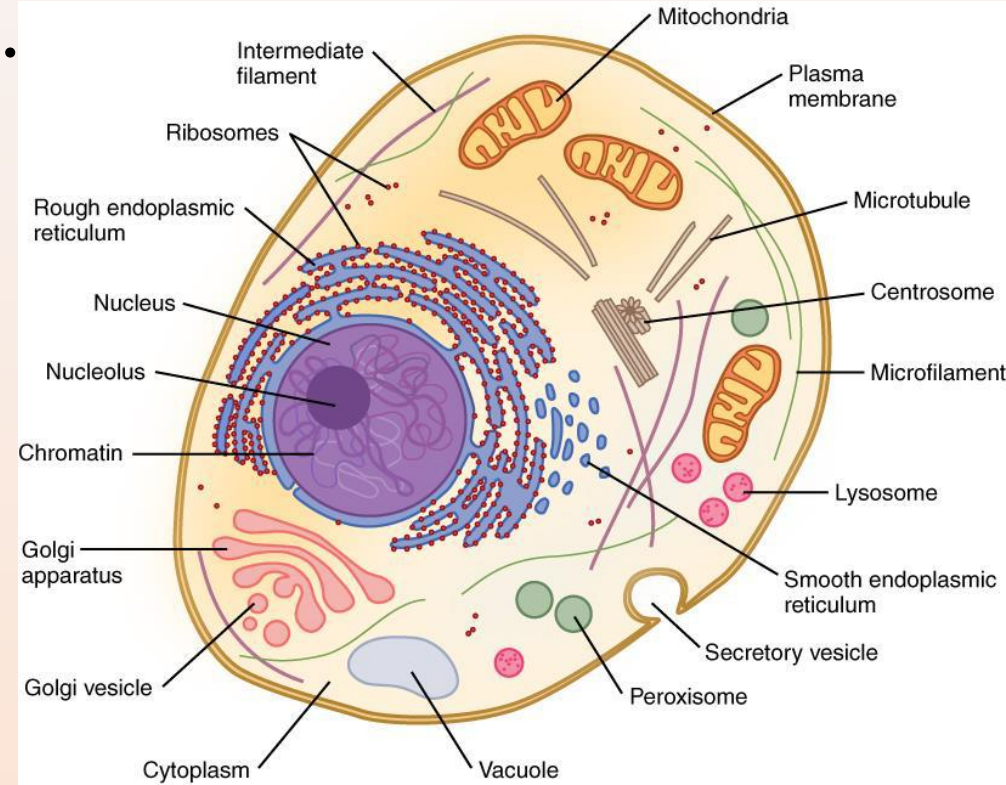
1.minerals 2.essential amino acids 3.essential fatty acids 4.water-soluble vitamins 5.fat- soluble vitamins

Cell structures and functions

- Cells: are a major part of our bodies, Is a structure and function units in all organisms. The human body has something on the order of 10 trillion cells

all working in harmony to keep us alive.

Cells are fundamental building blocks for many of the tissues and organs of our bodies.

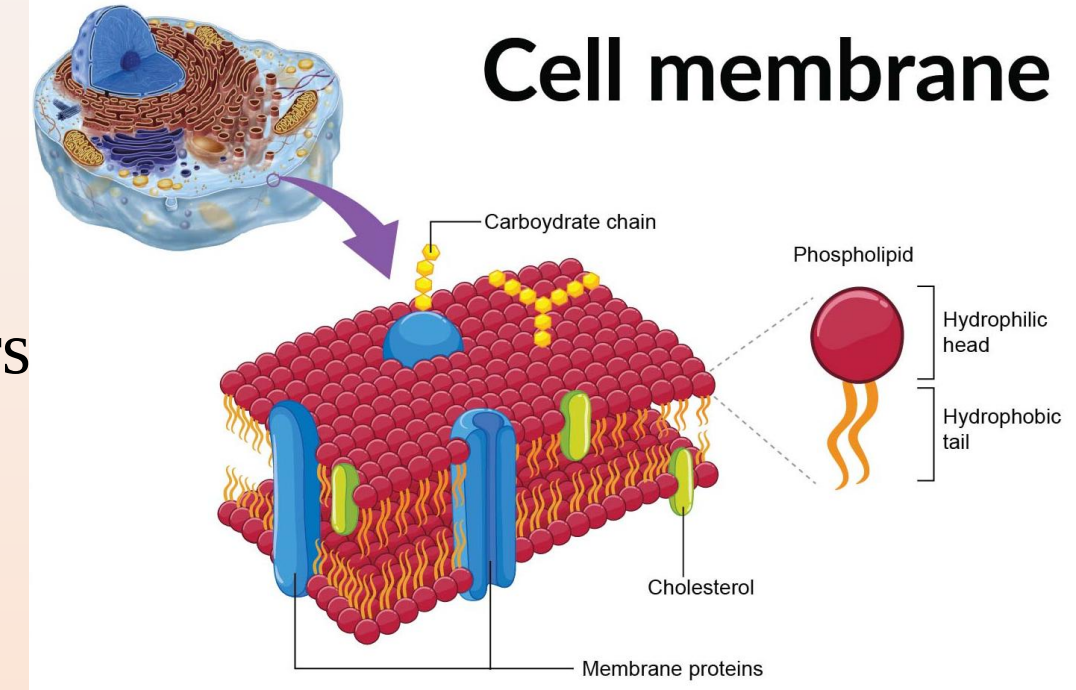


Cell Membrane

The **cell membrane (plasma membrane)** is a thin, flexible barrier that surrounds the cell.

Functions:

- **Protection**: separates internal contents from the external environment.
- **Selective transport**: regulates movement of nutrients, gases, and wastes.
- **Communication**: receptors detect signals (hormones, neurotransmitters).
- **Support**: maintains cell shape and anchors the cytoskeleton.



Structure of cell membrane

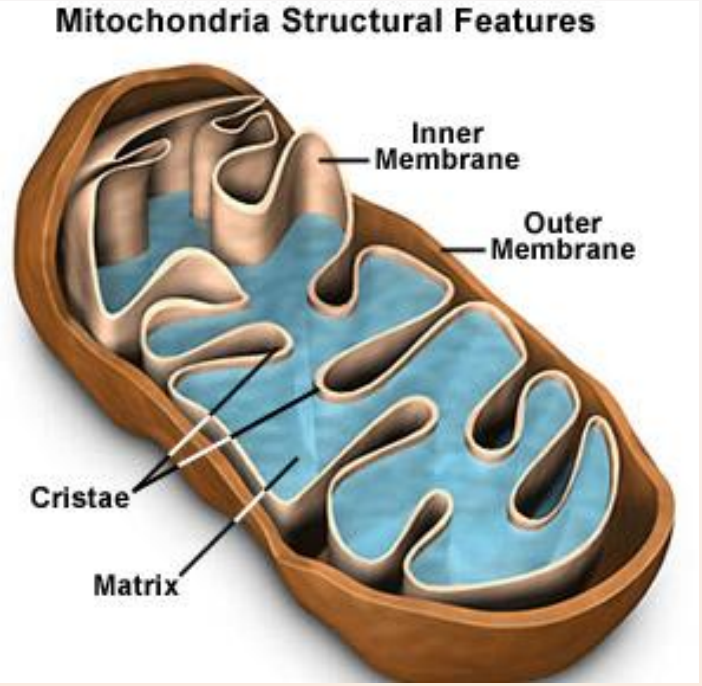
- **Phospholipid bilayer** with embedded proteins.
- Hydrophilic heads (water-loving) face outside & inside.
- Hydrophobic tails (water-fearing) face inward.
- Contains cholesterol (flexibility) and glycoproteins (recognition).
- Contains a number of proteins.

Some of these proteins act as channels to allow substances to pass through the membrane.

Others act as receptors that receive information carried by proteins.
Still others act as connection points for other cells to attach. These are known as intercellular junctions.

- **Cytoplasm:** The fluid inside the cell. It Holds the **cytoskeleton**, which supports and organizes the cell.
- **Endoplasmic Reticulum (ER)**
- Two types:
  - **Rough ER**: has ribosomes → makes proteins.
  - **Smooth ER**: no ribosomes → makes lipids (fats).
- **Ribosomes** help build proteins using RNA and enzymes.
- **Golgi Apparatus**
- Packs and ships proteins made in the ER to other parts of the cell or outside the cell.
- Producing vesicles containing **lysosomes**: have enzymes that break down debris in the cell.

- **Mitochondrion**
- Known as the **“powerhouse” of the cell**.
- Makes energy (ATP) from fuel like glucose.
- Inside has folds called **cristae**, which hold enzymes for energy production.



Centrosome

- Makes the **mitotic spindle** to separate chromosomes during cell division.
- Has two hollow cylinders called **centrioles**, made of proteins.

Cilia and Flagella: Protein structures for movement.

- **Cilia**: many, short hairs.
- **Flagellum**: one, long tail (e.g., sperm cell).

Microfilaments & Microtubules

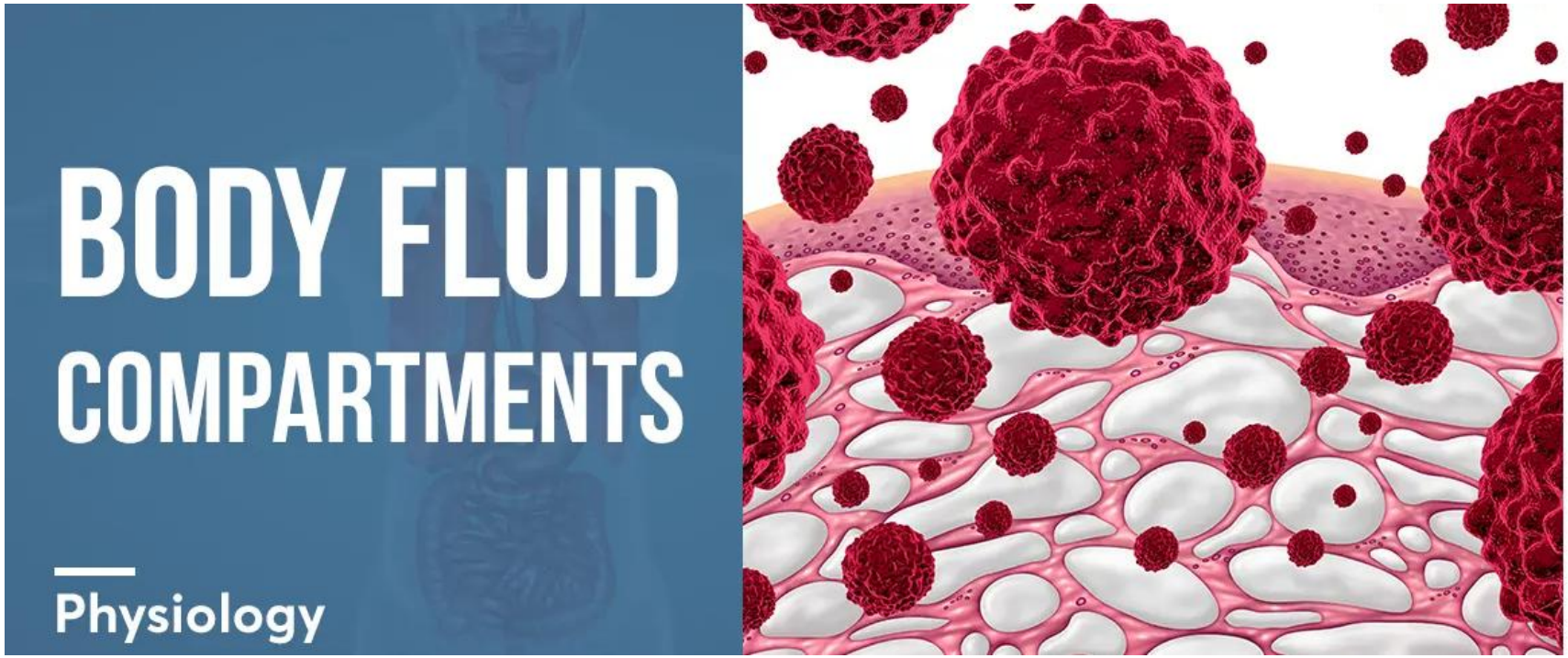
- **Microfilaments**: solid proteins that support the cell (part of cytoskeleton).
- **Microtubules**: hollow proteins that help with transport inside the cell.

Nucleus: The cell's control center; contains DNA.

Surrounded by a membrane.

Inside is the **nucleolus**, which makes ribosomes.

Lecture 3



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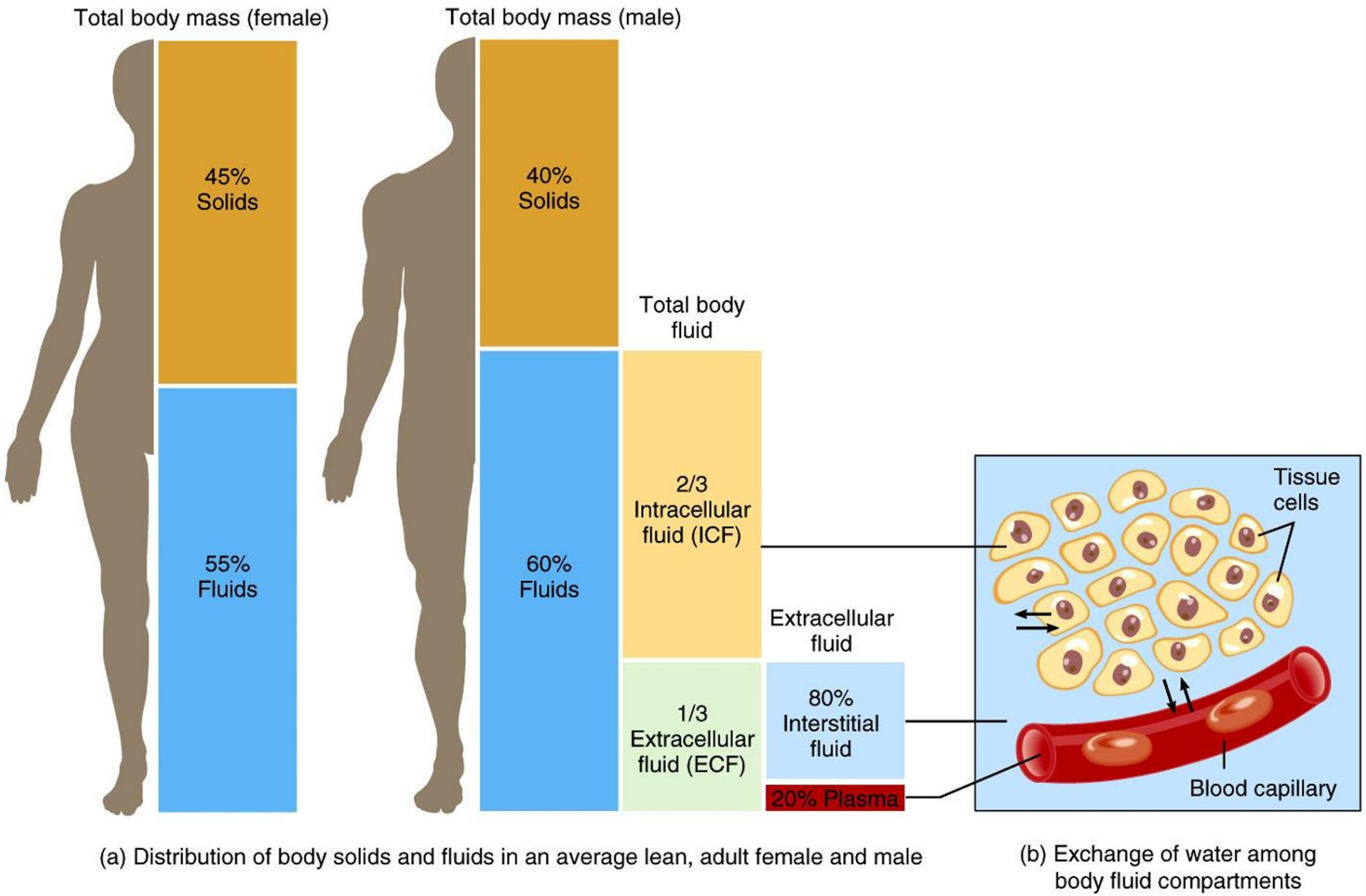
Body fluids

- Body fluids are liquids originating from inside the bodies of living humans. They include fluids that are excreted or secreted from the body. Human blood, body fluids
- □ Total amount of fluids in the human body is approximately 70% of body weight.
- □ Body fluid has been divided into two compartments

– Intracellular fluid (ICF) □ Inside the cells, 55% of total body water

– Extracellular fluid (ECF) □ Outside the cells, 45% of total body water



(a) Distribution of body solids and fluids in an average lean, adult female and male

(b) Exchange of water among body fluid compartments

Composition of body fluids

- Organic substances (Glucose ,Amino acids ,Fatty acids ,Hormones, Enzymes)
- Inorganic substances
- Sodium
- Potassium
- Calcium
- Magnesium
- Chloride
- sulphate
- Phosphate

The pH of ECF is 7.4. The pH of ICF is 7.0.

Importance of Body Fluids

1. Transport of substances: Carry nutrients, gases (O_2, CO_2), and wastes to and from cells.
2. Medium for chemical reactions: Provide the aqueous environment for metabolic processes.
3. Regulation of body temperature: Through sweating and blood circulation.
4. Lubrication and protection: Synovial fluid in joints, cerebrospinal fluid around brain/spinal cord.
5. Maintenance of pH and electrolyte balance: Buffers (like bicarbonate) keep blood pH stable. Electrolytes (Na^+, K^+, Cl^-, etc.) maintain osmotic balance.
6. Communication: Hormones and signaling molecules are transported in fluids

Distribution Of Body Fluids

Total water in the body is about 40 L. It is distributed into two major compartments

1. Intracellular fluid (ICF): Its volume is 22 L and it forms 55% of the total body water

2. Extracellular fluid (ECF): Its volume is 18 L and it forms 45% of the total body water. ECF is divided into 5 subunits:

i. Interstitial fluid and lymph (20%)

ii. Plasma (7.5%)

iii. Fluid in bones (7.5%)

iv. Fluid in dense connective tissues like cartilage (7.5%)

v. Transcellular fluid (2.5%) that includes:

a. Cerebrospinal fluid

b. Intraocular fluid

c. Digestive juices

d. Serous fluid – intrapleural fluid and pericardial fluid

e. Synovial fluid in joints

f. Fluid in urinary tract.

Tonicity

- Tonicity = effect of a solution on the movement of water across cell membranes.
- Effective molecules (e.g., Na^+, glucose) → move slowly, influence water movement.
- Ineffective molecules (e.g., urea, alcohol) → move rapidly, do not influence water movement.

Types of Solutions

1. Isotonic

Same concentration as body fluids.

Example: **0.9% NaCl (normal saline)**, **5% glucose**.

Effect on cells: no water movement → cells stay the same.

2. Hypertonic

Higher concentration than body fluids.

Example: **2% NaCl**.

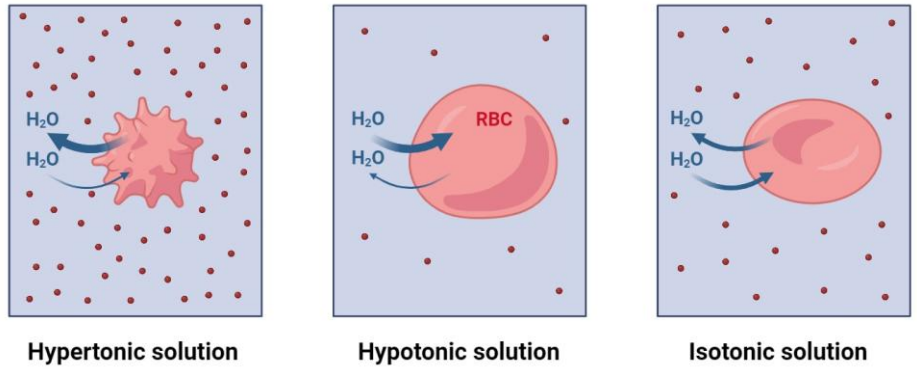
Effect on cells: water leaves cells (exosmosis) → cells shrinl

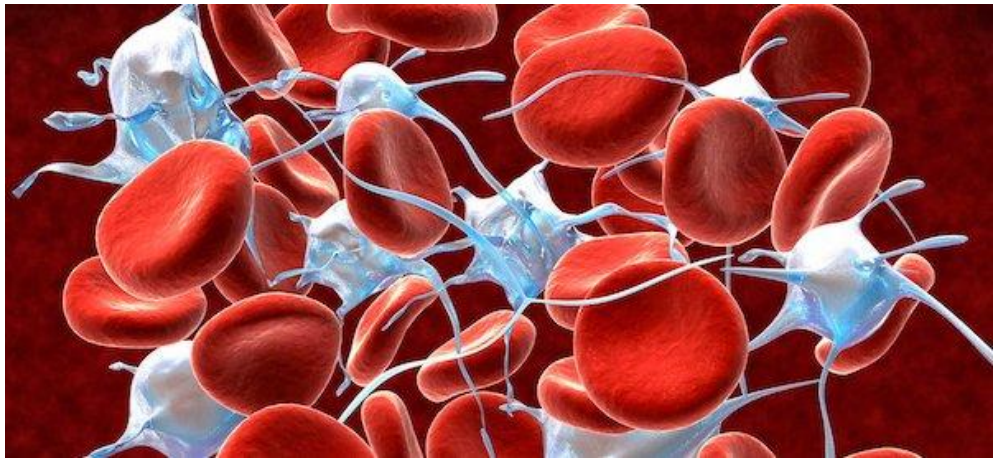
3. Hypotonic

Lower concentration than body fluids.

Example: **0.3% NaCl**.

Effect on cells: water enters cells (endosmosis) → cells swell.





Blood

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Blood : - is a connective tissue in fluid form.

It is considered as the ‘fluid of life’ because it carries oxygen from lungs to all parts of the body and carbon dioxide from all parts of the body to the lungs.

is known as ‘fluid of growth’ because it carries nutritive substances from the digestive system and hormones from endocrine gland to all the tissues.

The blood is also called the ‘fluid of health’ because it protects the body against the diseases and gets rid of the waste products and unwanted substances by transporting them to the excretory organs like kidneys.

Properties of Blood

1. Color: Blood is red in color. Arterial blood is scarlet red because it contains more oxygen and venous blood is purple red because of more carbon dioxide.

2. Volume: Average volume of blood in a normal adult is 5 L. In a newborn baby, the volume is 450 ml.

It increases during growth and reaches 5 L at the time of puberty. In females, it is slightly less and is about 4.5 L.

3. Reaction and pH: Blood is slightly alkaline and its pH in normal conditions is 7.4.

4. Specific gravity: Specific gravity of total blood : 1.052 to 1.061 Specific gravity blood cells : 1.092 to 1.101, Specific gravity of plasma : 1.022 to 1.026

5. Viscosity: Blood is five times more viscous than water. It is mainly due to red blood cells and plasma proteins.

Composition of Blood

- Blood contains the formed elements: the blood cells and the liquid portion known as plasma.
- Blood cells Three types of cells are present in the blood:

1. Red blood cells or erythrocytes
2. White blood cells or leukocytes
3. Platelets or thrombocytes

Plasma:

is a straw-colored clear liquid part of blood.

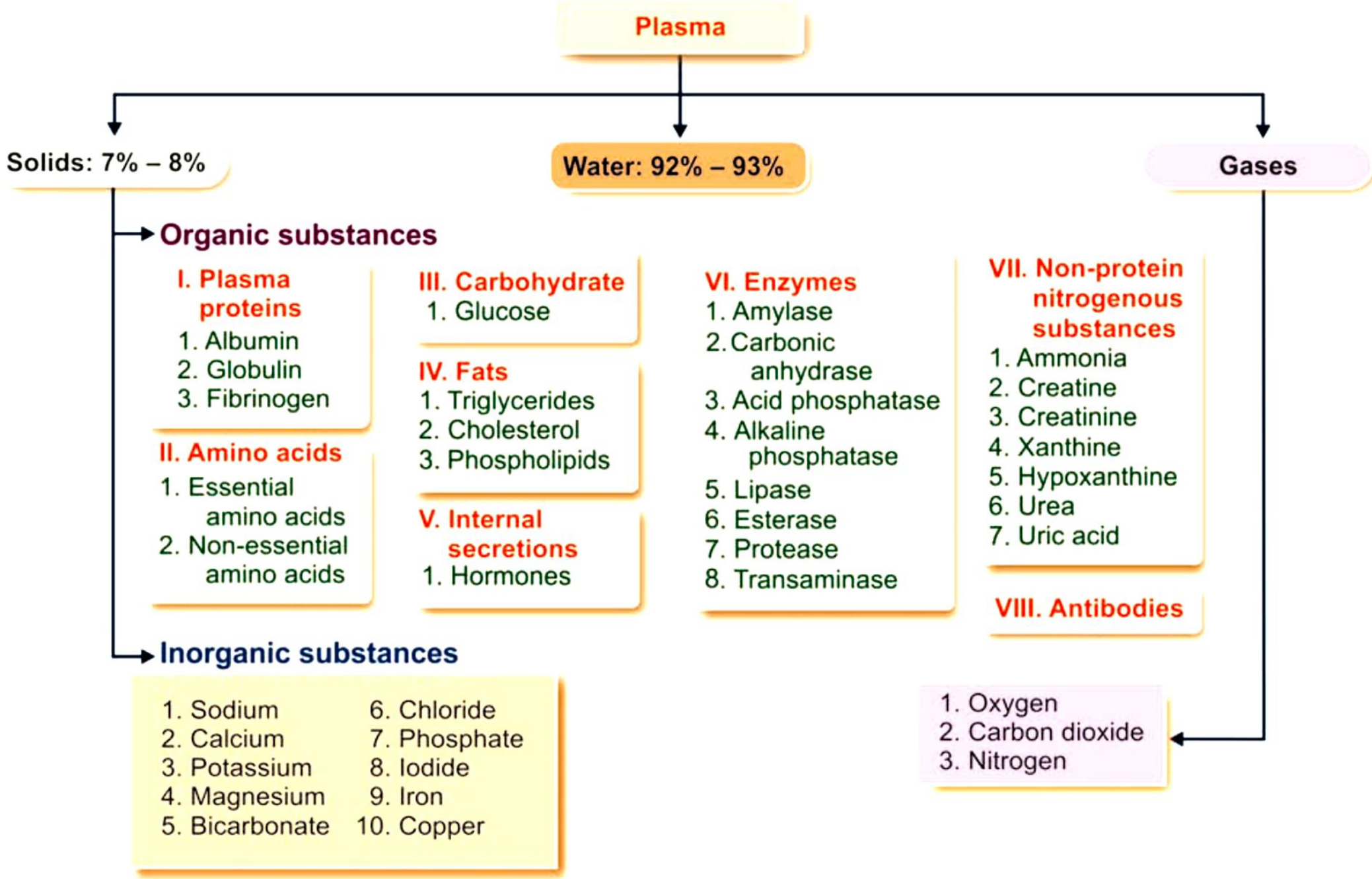
It contains 91% to 92% of water and 8% to 9% of solids.

The solids are the organic and the inorganic substances.

Plasma proteins are:

1. Serum albumin
2. Serum globulin
3. Fibrinogen.

Fibrinogen is absent in serum because, it is converted into fibrin during blood clotting.


Plasma
Solids: 7% – 8%
Water: 92% – 93%
Gases
Organic substances
I. Plasma proteins
1. Albumin
2. Globulin
3. Fibrinogen
II. Amino acids
1. Essential amino acids
2. Non-essential amino acids
III. Carbohydrate
1. Glucose
IV. Fats
1. Triglycerides
2. Cholesterol
3. Phospholipids
V. Internal secretions
1. Hormones
VI. Enzymes
1. Amylase
2. Carbonic anhydrase
3. Acid phosphatase
4. Alkaline phosphatase
5. Lipase
6. Esterase
7. Protease
8. Transaminase
VII. Non-protein nitrogenous substances
1. Ammonia
2. Creatine
3. Creatinine
4. Xanthine
5. Hypoxanthine
6. Urea
7. Uric acid
VIII. Antibodies
Inorganic substances
1. Sodium
2. Calcium
3. Potassium
4. Magnesium
5. Bicarbonate
6. Chloride
7. Phosphate
8. Iodide
9. Iron
10. Copper
1. Oxygen
2. Carbon dioxide
3. Nitrogen

Albumin/Globulin Ratio

Ratio between plasma level of albumin and globulin is called albumin/globulin (A/G) ratio.

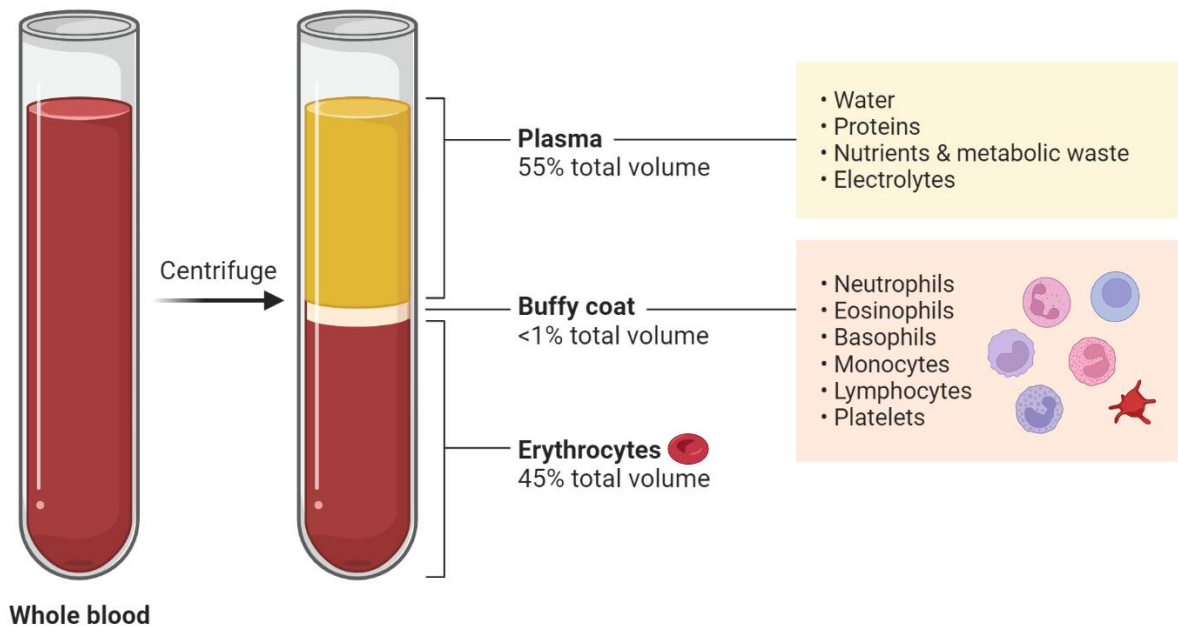
It is an important indicator of some diseases involving **liver or kidney**.

Normal A/G ratio is 2 : 1

Plasma proteins are separated by the following methods:

- **Electrophoresis**
- **Chromatography**
- **Precipitation**
- **Centrifugation**
- **Filtration**
- **Ethanol fractionation**

Blood and Its Components



ORIGIN OF PLASMA PROTEINS

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1. In Embryo

-In embryonic stage, the plasma proteins are synthesized by the mesenchyme cells.

-The albumin is synthesized first and other proteins are synthesized later.

2. In Adults

In adults, the plasma proteins are synthesized mainly from **reticuloendothelial cells of liver.**

The plasma proteins are synthesized also from **spleen, bone marrow**, disintegrating blood cells and general tissue cells. **Gamma globulin is synthesized from B lymphocytes.**

FUNCTIONS OF PLASMA PROTEINS

1. Role in Coagulation of Blood Fibrinogen is essential for the coagulation of blood .

2. **Role in Body Defense: Gamma globulins** (or **immunoglobulins**) act as **antibodies**.

- They defend the body by reacting with **antigens** of harmful microbes.
- Help protect against diseases like **diphtheria, typhoid, influenza, hepatitis, rubella**, etc

3. Role in Transport Mechanism: The alpha and beta globulins play an important role in the transport of **metals** in the blood.

4. Plasma Proteins and Osmotic Pressure

- At the **capillary level**, most substances move between **blood and tissues**.
- **Plasma proteins** are **too large** to pass through capillary walls, so they stay in the blood.
- These proteins create **colloidal (oncotic) pressure ≈ 25 mm Hg**.
- **Albumin** causes most of this pressure, followed by **globulin**, then **fibrinogen** (least).

5. Plasma proteins, particularly the albumin, play an important role in regulating the acid base balance in the blood.

6. Role in Viscosity of Blood second stage Plasma proteins provide viscosity to the blood, which is important to maintain the blood pressure.

7. Role in Erythrocyte Sedimentation Rate

8. Role in Suspension stability of Red Blood Cells

9. Role in Production of Trephone Substances

10. Role as Reserve Proteins.

Serum

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Serum

- Serum is the clear straw-colored fluid that oozes from blood clot.
- **Blood Clotting**

When blood is collected or exposed to air, it **clots**.

Fibrinogen changes into **fibrin** (a thread-like protein).

Blood cells get trapped in the fibrin, forming a **clot**.

After about **45 minutes**, **serum** (clear fluid) slowly oozes out of the clot.

- In labs, serum is separated from blood by centrifuging (spinning).The serum volume is about 55% of total blood — same as plasma.

Difference from plasma:

Serum has no fibrinogen **(it’s used up during clotting).It still contains all other plasma components.**

Serum = Plasma – Fibrinogen

Functions of Blood

1-Nutritive Function of Blood

Blood carries **nutrients** (glucose, amino acids, fats, vitamins) from the **digestive tract** to all body cells.

These nutrients are used for **energy**, **growth**, and **repair**.

2- Respiratory Function Transport of respiratory gases is done by the blood.

- **3. Excretory Function**
- Blood carries **waste products** from tissues to **kidneys, liver, and skin** for removal.
- **4. Transport of Hormones & Enzymes**
- Blood carries **hormones** from endocrine glands to target organs.
- Also transports **enzymes** for body functions.

5. Regulation of Water Balance

Helps **control water content** in body tissues.

6. Regulation of Acid–Base Balance

Plasma proteins and **hemoglobin** act as **buffers** to keep body pH normal.

7. Regulation OF Body Temperature

It is responsible for maintaining the thermoregulatory mechanism in the body.

- **8. Storage Function**
- Blood stores **water, proteins, glucose, sodium, and potassium**.
- These can be used when the body faces **starvation, fluid, or electrolyte loss**.

- **9. Defensive Function**

White blood cells (WBCs) protect the body from infection.

- **Neutrophils & monocytes:** eat bacteria (**phagocytosis**).
- **Lymphocytes:** build **immunity**.
- **Eosinophils:** help in **detoxifying and removing foreign proteins**

Physiology of Red blood cells (RBCs)

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Red blood cells (RBCs) :- are also known as erythrocytes (erythros = red). Normally**, the RBCs are non-nucleated, disk shaped and flat biconcave, Central portion is thinner and periphery is thicker.**

Normal value :- RBC count ranges between 4 and 5.5 million/cu mm of blood. In adult

-Erythrocytes lack a nucleus and mitochondria

-They get energy from anaerobic respiration .

-The unique shape : provides an increased surface area through which gas can diffuse.

- Its Lifespan about: 120 days.

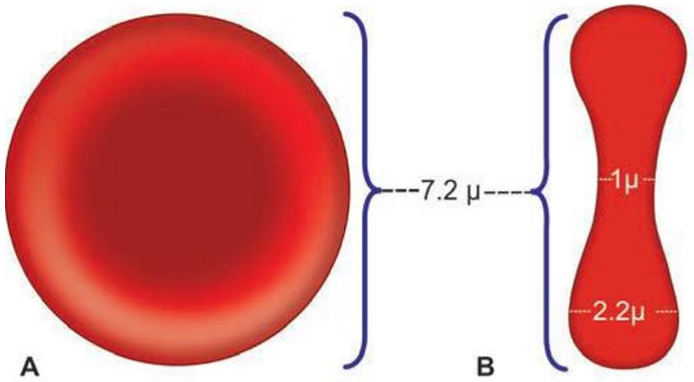

figure 1: Dimensions of RBC.
A. Surface view, B. Sectioned view.

FUNCTIONS OF RED BLOOD CELLS

- 1. Transport of Oxygen from the Lungs to the Tissues
- 2. Transport of Carbon Dioxide from the Tissues to the Lungs
- 3. Buffering Action in Blood
- 4. In Blood Group Determination
- 5. Regulation of blood flow
- 6. Regulation of blood pressure. How?

They make nitric oxide (NO), which widens blood vessels (vasodilation).They also release ATP when blood flow increases, helping relax vessel walls. This keeps blood pressure normal, especially when oxygen is low.

Hematopoiesis

- All cells arise from same blood stem cells **(pluripotent hematopoietic stem cells**) . **Hematopoiesis** involves the proliferation , maturation and destruction of blood cells.
- **Erythropoiesis** The production of new RBCs to replace the old and died ones. It is stimulated by erythropoietin hormone.
- in the adults , all the RBCs are produced in marrow with a rate of 2.5 million RBCs/ sec.
- old RBCs removed from blood by phagocytic cells in liver, spleen and bone marrow. iron of the destroyed RBCs recycled back into hemoglobin production.

Factors necessary for erythropoiesis

Development and maturation of erythrocytes require variety of factors, which are classified into three categories:

1. General factors
2. Maturation factors
3. Factors necessary for hemoglobin formation.

General factors necessary for erythropoiesis are:

i**. Hormones : (Erythropoietin, Thyroxine, androgens, and growth hormone). But estrogen inhibits it.**

ii. Proteins, amino acids , lipids and carbohydrates.

iii. Iron for hemoglobin synthesis.

iv. Vitamins : Vitamin B12 and folic acid for DNA synthesis.

v . cytokines.